Aggregate and Farm-Level Productivity Growth in Tobacco: Before and After the Quota Buyout

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We examine the distortionary effects of agricultural policy on farm productivity by examining the response of U.S. tobacco farmers' productivity to the quota buyout of 2004. We focus on the impact of distortionary policy, i.e., the tobacco quota, by decomposing aggregate productivity growth into the contribution of farm-level productivity growth and the contribution of reallocation of resources among tobacco growers. We find that the aggregate productivity of Kentucky tobacco farms grew 44% between 2002 and 2007. The elimination of quota rental costs and reallocation of resources, including entry and exit, accounted for most of the post-buyout productivity growth.

Key words: Tobacco; Quotas; Aggregate Productivity Growth; Reallocation.

JEL codes: Q18, Q12, O47.

The Tobacco Transition Act of 2004 ended a 66-year-old federal farm program and replaced it with...nothing. The Transition Act, also known as the tobacco quota buyout, was a rapid and complete market liberalization: from one growing season to the next, U.S. tobacco production went from a policy environment of severe restrictions on production to a free market regime. Such a large and seemingly permanent policy change provides an opportunity to study the full effects of distortionary economic policy. In this article we seize this opportunity by analyzing the effects of the buyout on aggregate productivity growth in tobacco production. We focus on a single major tobacco-producing state: Kentucky.[1]

Under the federal tobacco program, the USDA annually set an aggregate limit on virtually all domestic tobacco production and supported the prices received by U.S. tobacco growers. In addition, in most states, tobacco quota could not be sold or leased across county lines. These and other restrictions of the quota program limited growers' ability to efficiently allocate land and other resources for tobacco production. The quotas were a source of economic rents for quota owners, but they were also a major expense for growers, many of whom leased some if not all of their quota. Economic theory predicts that removing the restrictions imposed by the quota program frees farmers to allocate resources to tobacco production more efficiently. To what extent has reallocation occurred? To what extent did reallocation of resources contribute to productivity growth in tobacco production after the buyout?

Previous economic research has studied the effects of the quota buyout. For example, Brown, Rucker, and Thurman (2007) analyzed the distortionary effects of the quota program and used county-level data and simulations to predict the effects of the quota buyouts on production. They calibrated their simulation models with historical data and predicted that in the medium run tobacco production would increase. In fact, tobacco production decreased. Dohlman, Foreman, and Da Pra (2009) report that after the 2004 buyout harvested acreage for burley leaf and flue-cured leaf fell by 30 and 25-percent, respectively (although flue-cured production subsequently recovered). Brown, Rucker, and Thurman (2007) acknowledge that "the exit of some tobacco growers" was a complicating issue to

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[1] Kentucky produces more tobacco than any state other than North Carolina. We focus on Kentucky and not North Carolina because estimates of tobacco quota rental rates are readily available for Kentucky for the period of interest.

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their analysis. Such a large number of grower exits changed sectoral dynamics so much that a well-calibrated tobacco-sector forecast model provided substantially incorrect forecasts.

In this article we focus on the total factor productivity of tobacco growers in Kentucky before and after the buyout. We use data from the 1997, 2002, and 2007 Censuses of Agriculture, linked longitudinally at the farm level. In contrast to previous research, the panel we construct allows us to decompose the effects of the buyout into the contributions of farms that continued producing tobacco and the contributions of entrants into and exiters from tobacco production.

Methodologically, we combine the aggregate productivity growth decompositions of Diewert and Fox (2010) and Petrin and Levinsohn (2010), adapted to the context of tobacco production in Kentucky before and after the quota buyout. The Petrin and Levinsohn approach allows us to decompose the aggregate productivity growth (APG) of continuing farms into the contributions of farm-level technical efficiency growth and APG due to reallocation of resources among continuing farms. The Diewert and Fox index number approach allows us to separately account for the contributions of continuing farms versus entering and exiting farms.

We find that the aggregate productivity of Kentucky tobacco farms decreased by 7.1% between 1997 and 2002 and increased by 44% between 2002 and 2007. Reallocation of resources played an important role in aggregate productivity growth. About 22 percentage points of the 44% post-buyout increase in aggregate productivity in Kentucky tobacco production was due to reallocation of inputs among continuing farms and entry into and exit from tobacco production among existing farms. The combined contributions of the elimination of quota rental costs and reallocation of resources accounted for most of the post-buyout aggregate productivity growth of Kentucky tobacco farms.

The Tobacco Quota Program, the Quota Buyout, and Trends in Kentucky Tobacco Production

Under the federal tobacco program, growers had to own or lease marketing quota in order to sell tobacco. Allocated by the federal government when the program started in 1938, quota was an asset with its own market, but it was not completely freely tradable. The program applied to the two major types of tobacco, burley and flue-cured. Each crop had unique rules. Here we discuss the burley program because burley makes up the vast majority of the value of tobacco production in Kentucky, where this article focuses.[2] Womach (2003) provides an overview of the program for both burley and flue-cured tobacco.

The quota program placed both geographic and temporal restrictions on the allocation of land and other resources to tobacco production. Starting in 1991, burley growers could buy or lease quota separately from the land on which the tobacco was grown. In most states, including Kentucky, burley quota could not be sold or leased across county lines. Quota could only be sold or leased to active growers. However, it could be inherited, and it could be retained by inactive growers. In the final years of the program, most quota was not owned by active growers (Womach 2004). Quota had to be used by the owner or leased to another grower in 2 out of 3 years or be forfeited.

In Kentucky, the average quota lease rate increased from about 27 cents per pound in 1997 to about 59 cents per pound in 2002. These averages obscure wide variation in quota lease prices across Kentucky counties, reflecting the county-level variation in marginal costs of tobacco production. Quota lease prices ranged from 5 to 48 cents per pound in 1997 and from 25 to 85 cents per pound in 2002.[3] Over the same period, the average (nominal) price of tobacco in Kentucky increased only slightly from \$1.90 per pound in 1997 to \$2.02 per pound in 2002.[4] Thus quota rental costs were a significant and increasing fraction of the price of tobacco. The large across-county variation in quota lease prices also provides some evidence of the extent to which the quota program distorted tobacco production decisions. In the absence of restrictions on the across-county trade of quota, we would expect tobacco production to be reallocated to counties with lower

[2] Prior to the buyout in 1997 and 2002, respectively 96% and 91% of the value of tobacco produced in Kentucky was from burley tobacco, with fire-cured and dark tobacco accounting for the rest. By 2007, fire-cured and dark tobacco accounted for the 24% of the value of Kentucky tobacco production, with burley accounting for the remaining 76%. See the NASS Quickstats website at http://www.nass.usda.gov/QuickStats.

[3] We thank Will Snell of the University of Kentucky for providing us with his unofficial estimates of the quota lease prices for every Kentucky tobacco-producing county over the period 1991–2004.

[4] See the NASS Quickstats website: http://quickstats.nass.usda.gov.

marginal costs until quota lease prices were equalized across counties (Rucker, Thurman, and Sumner 1995).

The design of the quota buyout also likely affected production decisions. Quota owners received \$7 per pound of quota. Importantly, growers who produced tobacco between 2002 and 2004 received an additional \$3 per pound of quota–the so-called "grower benefit." Various proposed versions of the quota buyout were discussed in policy circles and tobacco communities years in advance of the Transition Act. In light of these facts, it seems likely that, in order to capture the grower benefit, some quota owners continued or even entered tobacco production instead of renting out their quota in 2002.

Because of increasing foreign competition and decreasing domestic demand, U.S. tobacco production declined steeply between 1997 and 2002.[5] Kentucky followed the national trend, with the number of Kentucky farms with tobacco sales decreasing from 46,792 in 1997 to 29,253 in 2002.[6] After the buyout, demand for tobacco products in the U.S. continued to decline, and the cost of inputs to production such as hired labor and fuel increased. Net exports of U.S. tobacco leaf increased after the buyout, in part because the price of U.S. leaf declined when the effective price support of the quota program was removed (Dohlman, Foreman, and DaPra 2009). However, after the buyout the number of tobacco farms continued to decline, both nationally and in Kentucky. By 2007, there were only 8,113 tobacco farms in Kentucky.

A Brief Review of Reallocation and Aggregate Productivity Growth Decompositions

Hulten (1978) shows that in a perfectly competitive economy with no distortions, adjustment costs, or other frictions, aggregate productivity growth is equal to the weighted sum of enterprise-level technical efficiency growth rates, i.e., aggregate technical efficiency growth. In a seminal paper, Baily, Hulten, and Campbell (1992, BHC hereafter) define aggregate productivity growth as the weighted sum of plant-level technical efficiencies. Then they decompose this index into the output-share-weighted sum of the growth rates of plant-level technical efficiency (the "within" component), and the technical-efficiency-weighted sum of the changes in plant-level output shares (the "between" component). The between component is usually interpreted as measuring the contribution of reallocation to aggregate productivity growth. Several other authors refine the BHC decomposition to include additional terms in the decomposition (Griliches and Regev 1995; Olley and Pakes 1996; Foster, Haltiwanger, and Krizan 2001). All of these decompositions share the feature that aggregate productivity is defined as the weighted sum of plant-level (or firm-level) productivity.

All of the BHC-like decompositions share a common problem. As emphasized by Petrin and Levinsohn (2010, P-L hereafter), in an economy in competitive equilibrium with no distortions, adjustment costs, or other frictions, further reallocation of resources does not contribute to aggregate productivity growth. In other words, in such an economy, the "between" component in a BHC decomposition does not measure the contribution of reallocation to aggregate productivity growth. Both P-L and Basu and Fernald (2002) point out that when there are adjustment costs or markups over marginal cost or other distortions (such as taxes, subsidies, or quotas), (i) aggregate productivity growth is generally not equal to aggregate technical efficiency growth and (ii) reallocation of resources can contribute to aggregate productivity growth. These theoretical results imply that in an economy in which markups or distortions such as taxes or subsidies or quotas are important, the BHC index misses an important component of aggregate productivity growth. Recent empirical results using manufacturing data from the U.S., Japan, and Chile show that the difference between aggregate productivity growth and the growth rate of a BHC type of index can be quite large (Petrin, White, and Reiter 2011; Kwon, Narita, and Narita 2009; Petrin and Levinsohn 2010).

Growing empirical and theoretical literatures have highlighted the importance of resource reallocation for aggregate productivity growth (Melitz 2003; Bernard et al. 2003; Lentz and Mortensen 2008; Petrin, White, and Reiter 2011). Recent studies by Restuccia and Rogerson (2008) and Hsieh and Klenow (2009) have also found that

[5] Domestic demand for tobacco leaf declined for a variety of reasons, including health concerns associated with tobacco products, increasing state and Federal excise taxes on tobacco products, and increased restrictions on smoking in public (Dohlman, Foreman, and DaPra 2009).

[6] These are USDA's published totals. See the NASS Quickstats website: http://quickstats.nass.usda.gov.

within-industry heterogeneity in distortions (e.g., taxes or subsidies) may have important effects on aggregate total factor productivity. Both within-industry heterogeneity in distortions (because of restrictions on leasing quota across counties) and reallocation of resources were clearly important features of Kentucky tobacco production in the years before and after the quota buyout. In light of these facts, we use an aggregate productivity decomposition that accounts for the role of heterogeneous distortions and reallocation in determining the aggregate productivity growth of Kentucky tobacco farms, namely the P-L decomposition.

The Petrin-Levinsohn Decomposition

Petrin and Levinsohn (2010) show how to decompose aggregate productivity growth into the separate contributions of firm-level technical efficiency growth and the reallocation of each factor of production across firms. We apply the P-L methodology, except that we adapt it to U.S. tobacco production before and after the quota buyouts. We follow the discussion of the theory in P-L. For the purpose of explaining the theory, we assume that all tobacco farms only produce tobacco.[7] Each farm i's production technology can be represented as[8]

$$(1)\qquad Q_i = F(X_i, M_i, \omega_i).$$

where $X_i = (X_{i1}, \ldots, X_{iK})$ is a vector of primary input usage (land, labor, buildings and machinery) on farm i and $M_i = (M_{i1}, \ldots, M_{iJ})$ is the vector of intermediate inputs (fertilizer, agricultural chemicals, seeds, fuel, etc.). Finally, ω_i is the level of farm i's technical efficiency.

Here we adapt the P-L framework for the purpose of measuring the aggregate productivity of tobacco farms under the quota program. P-L defines aggregate productivity change as the change in aggregate *final demand* minus the change in aggregate costs, where a firm's final demand Y_i is its output Q_i minus the portion of its output that is used as intermediate input by all other firms: $Y_i = Q_i - \sum_j M_{ji}$, where M_{ji} denotes output from firm i used as intermediate input at firm j. If we sum across all firms, aggregate final demand is equal to aggregate value-added. Since we are focusing on a single industry (tobacco production) and we do not observe the final demand for tobacco farms' output, we can write this industry's aggregate productivity change as the change in the aggregate *output* of the industry minus the change in aggregate costs:

$$(2)\qquad dAP \equiv \sum_i P_i dQ_i - \sum_i \sum_k W_{ik} dX_{ik} - \sum_i \sum_j P_{ij} dM_{ij} - \sum_i R_i dQuota_i,$$

where the summation is over Kentucky tobacco farms. P_i denotes the price of farm i's tobacco, and thus $\sum_i P_i dQ_i$ is equal to the instantaneous change in aggregate output holding prices constant. W_{ik} is the marginal cost of the k^{th} primary input and dX_{ik} is the instantaneous change in the use of that primary input at farm i. P_{ij} is the price of intermediate input j at farm i, and dM_{ij} is the instantaneous change in the use of that input. The last term on the right side of equation (2) captures the direct cost of renting quota, where R_i is the rental rate of quota for farm i, and $dQuota_i$ is i's change in quota usage. For farms that own quota for all of the tobacco that they sell, R_i captures the opportunity cost at the margin of not renting out their quota. Quotas can have an indirect effect on aggregate productivity by driving a wedge between value marginal products and marginal costs. At the level of the entire economy, the quota rents themselves are just a redistribution of wealth from renters to owners, and do not *directly* affect aggregate productivity.[9] However, as noted above, by the end of the tobacco program, most quota was not owned by growers, and quota rental was a significant cost for tobacco growers. Since we are analyzing aggregate productivity at the level of the tobacco production industry, we include changes in these quota rental costs as part of our measure of aggregate productivity.

[7] In the data many tobacco farms also produce other crops and/or livestock. We discuss how we deal with multi-output farms in the measurement section below.

[8] Petrin and Levinsohn (2010) allow for fixed costs of production, which are subtracted from output. Here we abstract from fixed costs.

[9] We thank Tom Vukina for pointing this out.

P-L shows that if the farm-level production function F is differentiable, then the change in aggregate productivity in equation (2) can be decomposed as:

$$(3) \qquad dAP = \sum_i \sum_k \left(P_i \frac{\partial F}{\partial X_k} - W_{ik} \right) dX_{ik} + \sum_i \sum_j \left(P_i \frac{\partial F}{\partial M_j} - P_j \right) dM_{ij} - \sum_i R_i dQuota_i + \sum_i P_i d\omega_i,$$

Equation (3) decomposes the change in aggregate productivity into the contributions of, respectively, reallocation of primary and intermediate inputs, the reallocation of quota, and farm-level technical efficiency change. The first two double-summation terms on the right side of equation (3) measure the contributions of reallocation of primary (X) and intermediate (M) inputs. Within these terms, the expressions $P_i \frac{\partial F}{\partial X_k} - W_{ik}$ and $P_i \frac{\partial F}{\partial M_j} - P_j$ are gaps or wedges reflecting the difference between the farm's value marginal product and its marginal cost for each input. If the value marginal product is equal to the marginal cost for every input on every farm, then reallocation of inputs will not contribute to aggregate productivity change. In this case, in the absence of quota rental costs, the change in aggregate productivity is just the price-weighted sum of the changes in farm-level technical efficiencies: $dAP = \sum_i P_i d\omega_i$. However, if there are gaps between the value marginal products and the marginal costs for any of the inputs, then reallocation also contributes to aggregate productivity change. Note that the P-L decomposition does not force us to take a stand on what is causing the gaps between marginal products and marginal costs. If there are gaps for any reason, then the first two double summations in equation (3) measure the contribution of reallocation to aggregate productivity change. In the case of Kentucky tobacco production before the buyout, quota lease prices varied widely across counties, suggesting that restrictions on reallocating quota across counties drove wedges been marginal products and marginal costs.

If we divide equation (2) by the aggregate value-added of the industry and do a bit of algebra, we obtain the following equation for aggregate productivity growth (APG):

$$(4) \qquad APG = \sum_i D_i dlnQ_i - \sum_k \sum_i D_i c_{ik} dlnX_{ik} - \sum_j \sum_i D_i c_{ij} dlnM_{ij} - \sum_i c_{iq} dlnQuota_i$$

where $D_i = \frac{P_i Q_i}{\sum_{i=1}^N P_i Y_i}$ is the Domar (1961) weight, $c_{ik} = \frac{W_{ik} X_{ik}}{P_i Q_i}$ is the revenue share of primary input k, $c_{ij} = \frac{P_{ij} M_{ij}}{P_i Q_i}$ is the revenue share of intermediate input j, and $c_{iq} = \frac{R_i Quota_i}{P_i Q_i}$ is the revenue share of quota rental costs. The Domar weight takes into account the fact that some of farm i's output will contribute to aggregate productivity growth because it will be used as intermediate input in other industries.

If we divide both sides of equation (3) by the aggregate value-added of the industry and do some more algebra, then aggregate productivity growth in equation (4) can be decomposed as:

$$(5) \qquad APG = \sum_i D_i \sum_k (\varepsilon_{ik} - c_{ik}) dlnX_{ik} + \sum_i D_i \sum_j (\varepsilon_{ij} - c_{ij}) dlnM_{ij} - \sum_i D_i c_{iq} dlnQuota_i + \sum_i D_i dln\omega_i,$$

where D_i is the Domar weight, ε_{ik} and ε_{ij} are the elasticities of output with respect to primary and intermediate inputs, $c_{ik} = \frac{W_{ik} X_{ik}}{P_i Q_i}$ and $c_{ij} = \frac{P_j M_{ij}}{P_i Q_i}$ are the respective farm-specific revenue shares for primary and intermediate inputs, and $dln\omega_i$ is the growth rate of farm i's technical efficiency, where the base is Q_i: $dln\omega_i \equiv \frac{d\omega_i}{Q_i}$. Equation (5) decomposes aggregate productivity *growth* into the contributions of, respectively, reallocation of primary and intermediate inputs, the reallocation of quota, and farm-level technical efficiency growth. Now the gap expressions $\varepsilon_{ik} - c_{ik}$ and $\varepsilon_{ij} - c_{ij}$ represent differences between the output elasticities and the revenue-shares, but the intuition is the same as for the aggregate productivity change decomposition (equation 3): if markups, subsidies, quotas, or other distortions drive a wedge between an input's value marginal product and its marginal cost, then reallocation will contribute to aggregate productivity growth.

Discrete-Time Approximation and Dealing with Entry and Exit

The Petrin and Levinsohn (2010) theory is developed in continuous time. In the real world, data is collected at discrete intervals. We could approximate equation (4) with a Törnqvist index, which has many desirable properties (Diewert 1976). However, the Törnqvist index cannot be used to calculate the contribution of entering or exiting farms, since it is impossible to compute farm-level growth rates for farms that are observed in only one of the two consecutive periods. Entering and exiting tobacco farms made up a significant portion of the changes in total tobacco production, and so it is important for us to account for those farms when measuring aggregate productivity growth.

Diewert and Fox (2010, D-F hereafter) develop a multilateral index number approach to measuring the contribution of entering and exiting firms to aggregate productivity growth. Since tobacco farms produce multiple outputs and use multiple inputs, we would ideally define farm-level productivity using the farm's entire vector of input and output prices and quantities. Unfortunately we do not observe all these prices and quantities–for most inputs we only observe expenditures. In this situation D-F suggest constructing firm-level "approximate output and input aggregates" using (deflated) revenues and costs. For simplicity of exposition we continue to assume that each farm has only one output. Thus for each farm i, approximate productivity in year t, Π_{it} is:

$$\Pi_{it} = \frac{P_{it}Q_{it}}{\sum_k W_{ikt}X_{ikt} + \sum_j P_{ijt}M_{jit} + R_{it}Quota_{it}} \tag{6}$$

where all the variables on the right side are defined above.[10]

Using this definition of farm-level productivity, an approximation of aggregate productivity is:

$$AP_t = \frac{\sum_i P_{it}Q_{it}}{\sum_i \left(\sum_k W_{ikt}X_{ikt} + \sum_j P_{ijt}M_{jit} + R_{it}Quota_{it}\right)} \tag{7}$$

where the outer summations are over all farms active in year t. Intuitively, this measures aggregate productivity as aggregate revenues over aggregate primary and intermediate input costs and quota rental costs.[11]

Let $cost_{it}$ denote farm i's costs in year t: $cost_{it} = \sum_k W_{ikt}X_{ikt} + \sum_j P_{ijt}M_{jit} + R_{it}Quota_{it}$. Aggregate productivity in year t can be decomposed as:

$$AP_t = \sum_{i \in C} s_{it}\Pi_{it} + \sum_{i \in E} s_{it}\Pi_{it} \tag{8}$$

where $s_{it} = \frac{cost_{it}}{\sum_i cost_{it}}$ is farm i's share of aggregate costs in year t, C denotes the set of farms that continued from $t-5$ to t, and E denotes the set of farms that entered between $t-5$ and t. Similarly, we can decompose aggregate productivity in year $t-5$ as:

$$AP_{t-5} = \sum_{i \in C} s_{i,t-5}\Pi_{i,t-5} + \sum_{i \in \chi} s_{i,t-5}\Pi_{i,t-5} \tag{9}$$

where again C denotes the set of farms that continue from $t-5$ to t, and χ is the set of farms that exit between $t-5$ and t. Approximate APG is then computed as $(AP_t - AP_{t-5})/AP_{t-5}$. Combining equations (8) and (9) and rearranging terms yields:

$$\begin{aligned} (10)\ APG_t &= \left[\sum_{i \in C}(s_{it}\Pi_{it} - s_{i,t-5}\Pi_{i,t-5})\right]/AP_{t-5} \\ &\quad + \left[\sum_{i \in E} s_{it}\Pi_{it} - \sum_{i \in \chi} s_{i,t-5}\Pi_{i,t-5}\right]/AP_{t-5} \end{aligned}$$

The first line of (10) approximates the contribution of continuing farms to APG, and the

[10] In practice we deflate the revenues and expenditures in equation (6) using state-level price indexes. Here we abstract from deflators for simplicity of exposition.

[11] Note that if we use equation (7) to derive the change in aggregate productivity resulting from an infinitesimal change in all of the inputs, holding prices constant, the result is equation (2).

second line approximates the contribution of farms identified as entrants and exits.

For *continuing* farms in the pre-buyout period, the P-L decomposition of APG into reallocation and technical efficiency growth in equation (5) can be approximated by the following Törnqvist index:

$$(11)\quad APG_{Ct} = \sum_{i\in C}\overline{D}_{it}\left[\sum_{k}(\overline{\varepsilon}_{ikt}-\overline{c}_{ikt})\Delta lnX_{ikt} + \sum_{j}(\overline{\varepsilon}_{ijt}-\overline{c}_{ijt})\Delta lnM_{ijt}\right] - \sum_{i\in C}\overline{D}_{it}\overline{c}_{iqt}\Delta lnQuota_{it} + \sum_{i\in C}\overline{D}_{it}\Delta ln\omega_{it}$$

where for any variable z, $\overline{z}_{it} = \frac{z_{it}+z_{i,t-5}}{2}$, Δ is the first difference operator, and C denotes the set of continuing tobacco farms. In the post-buyout period, we drop the quota rental costs in equation (11) for the same reason we exclude entrants and exits. After the buyout, all farms had zero quota, so we cannot measure the (negative) growth rate of quota for these farms. Substituting equation (11) into equation (10), for 1997–2002 we have:

$$(12)\quad APG_t = \sum_{i\in C}\overline{D}_{it}\left[\sum_{k}(\overline{\varepsilon}_{ikt}-\overline{c}_{ikt})\Delta lnX_{ikt} + \sum_{j}(\overline{\varepsilon}_{ijt}-\overline{c}_{ijt})\Delta lnM_{ijt}\right] - \sum_{i\in C}\overline{D}_{it}\overline{c}_{iqt}\Delta lnQuota_{it} + \sum_{i\in C}\overline{D}_{it}\Delta ln\omega_{it} + \sum_{i\in C}U_{it} + \left[\sum_{i\in E}s_{it}\Pi_{it} - \sum_{i\in\chi} \times s_{i,t-5}\Pi_{i,t-5}\right]/AP_{t-5}$$

where the residual term for continuers $\sum_{i\in C}U_{it}$ is the difference between the D-F APG approximation and the P-L APG approximation for continuers:

$$(13)\quad \sum_{i\in C}U_{it} \equiv \left[\sum_{i\in C}(s_{it}\Pi_{it} - s_{i,t-5}\Pi_{i,t-5})\right]/AP_{t-5} - \sum_{i\in C}\overline{D}_{it}\left[\sum_{k}(\overline{\varepsilon}_{ikt}-\overline{c}_{ikt})\Delta lnX_{ikt} + \sum_{j}(\overline{\varepsilon}_{ijt}-\overline{c}_{ijt})\Delta lnM_{ijt}\right] + \sum_{i\in C}\overline{D}_{it}\overline{c}_{iqt}\Delta lnQuota_{it} - \sum_{i\in C}\overline{D}_{it}\Delta ln\omega_{it}$$

Intuitively, the $\sum_{i\in C}U_{it}$ term accounts for the fact that the index of aggregate productivity in equation (10) includes changes in relative prices of inputs and output, whereas the Törnqvist approximation for continuers in equation (11) holds these prices constant. Equations (12) and (13) apply to the pre-buyout period. When we decompose APG for 2002–2007, we drop the quota reallocation term, $\sum_{i\in C}\overline{D}_{it}\overline{c}_{iqt}\Delta lnQuota_{it}$, from equations (12) and (13). As a result, for 2002–2007, the $\sum_{i\in C}U_{it}$ term also accounts for the fact the D-F decomposition in equation (10) includes changes in the costs of quota, but the P-L decomposition for continuers (for 2002–2007) does not.

To measure the contribution of each term to APG in equation (12), we calculate revenue shares, c_{ikt} and c_{ijt}, and cost shares s_{it} separately for each farm in each year. To measure the output elasticities ε_{ikt} and ε_{ijt} and the growth rate of farm-level technical efficiency, we estimate production functions, as described in the next section.

Production Function Estimation

We assume Kentucky tobacco farms' production technology can be approximated by a translog production function. Specifically, we estimate the following by OLS, OLS with county fixed effects, and using the Levinsohn and Petrin (2003, L-P hereafter) estimator, which attempts to address the input endogeneity issues pointed out by Marschak and Andrews (1944):[12]

$$(14)\quad lnQ_{it} = \beta_0 + \sum_{\kappa} \beta_\kappa lnZ_{i\kappa t} + \sum_{\kappa} \beta_\kappa (lnZ_{i\kappa t})^2 + \frac{1}{2}\sum_{\kappa}\sum_{l\neq\kappa} \beta_{\kappa l} lnZ_{i\kappa t} lnZ_{ilt} + u_{it}$$

where Q is *output* of farm i in year t, $Z_{i\kappa t}$ is primary or intermediate input κ, and u_{it} is an error term. For inputs, we use *land* (acres harvested), *labor* (including hired, contract and operator labor), *capital*, *intermediates*, and *livestock* expenses. The output elasticity for input κ is then derived as:

$$(15)\quad \frac{\partial lnQ}{\partial lnZ_\kappa} = \beta_\kappa + \sum_{l} \beta_{\kappa l} lnZ_{ilt}$$

Note that this allows the output elasticity to vary across farms and across years. Given a set of production function parameter estimates, our estimate of the log of technical efficiency of farm i in year t is the estimated intercept plus the residual: $ln\omega_{it} = \widehat{\beta}_0 + \widehat{u}_{it}$. We use $ln\omega_{it}$ and the estimated output elasticities in equation (15) to compute the APG decomposition in equation (12).

Tobacco Sector Dynamics

The buyout led to a major restructuring of tobacco production. The total number of Kentucky tobacco farms declined precipitously from 31,082 in 2002 to 8,113 in 2007.[13] At the same time, the average tobacco farm size in Kentucky more than doubled between 2002 and 2007. These dramatic changes indicate the magnitude of the distortion caused by tobacco quotas. We begin to get a sense of the reallocative process and extensive distortions by examining the changes in farm number and size.

We investigate the structural change in tobacco production by selecting Kentucky farms in the 1997, 2002, and 2007 Censuses of Agriculture that harvested tobacco in one or more of these years. For each time period, we classify farms into five categories: farm entrants, tobacco entrants, farm exits, tobacco exits, and continuers. Consider, for example, the dynamics between 1997 and 2002. Tobacco farms which are in the data in 1997 are defined as farm exits if they disappear from the sample in 2002 or "tobacco exits" if they continue farming but do not produce tobacco in 2002. Similarly, tobacco farms which are in our sample in 2002 are defined as farm entrants if they are not in our sample in 1997 or "tobacco entrants" if they were in the data but did not produce tobacco in 1997. Farms in our sample that produced tobacco in both 1997 and 2002 are continuers.

Table 1 shows the dynamics in two periods, 1997–2002 and 2002–2007, for farms in Kentucky that produced tobacco in 1997, 2002, or 2007.[14] Columns 1 and 3 report the dynamics for all farms in the sample over the two time periods, respectively. Columns 2 and 4 report the dynamics for just those farms that produced tobacco during the indicated time period. The farm exit rate was constant at about 40% in both intervals, but the tobacco exit rate jumped from 22% between 1997–2002 to 43% between 2002–2007. The table suggests that the transformation was more subtle than merely a mass exodus. For example, although 25,789 farms stopped producing tobacco between 2002 and 2007, the Censuses of Agriculture indicate that 2,820 farms *began* producing tobacco. Eighty percent of these entrants (2,290 farms) appeared to be new farms, and 20% (530 farms) were active farms that (re)entered tobacco production.[15]

[12] In order to take account of differences in weather that might affect productivity, we also estimated specifications in which we included county-level measures of rainfall and degree-days. However, the weather data had little effect on our production function estimates.

[13] Our estimate of the total number of Kentucky tobacco farms in 2007 matches the USDA's published count for farms with harvested tobacco acres. In 1997 and 2002, our totals are slightly different from the published totals for two reasons. First, published Agricultural Census totals reflect adjustments for undercoverage, but the adjustments for undercoverage have changed over time. Continuing farms that appear in two consecutive Censuses may have different weights in the published totals, but we have to choose a single weight for each farm. This also explains why the final numbers for 1997–2002 do not exactly match the initial numbers for 2002–2007. Second, our total tobacco farm counts in 1997 and 2002 are slightly different from the published totals because of difficulty matching longitudinal identifiers between 1997 and 2002, a problem affecting about 1% of our sample.

[14] These include all farms that produced any type of tobacco. Unfortunately the Census of Agriculture does not distinguish between types of tobacco.

[15] Because farm identifiers in the Agricultural Censuses sometimes change due to operator turnover or consolidation, it seems likely that some of the farms we identify as entrants and exits were in fact continuing farms that changed identifiers from one Census to the next. However, this is not the case for the 530 farms that

Table 1. Numbers of Continuing, Entering, and Exiting Kentucky Tobacco Farms, 1997–2002 & 2002–2007

		(1)	(2)	(3)	(4)
		1997–2002		2002–2007	
		Operating Farms	Tobacco Producing Farms	Operating Farms	Tobacco Producing Farms
Initial		53,649	51,309	42,306	31,082
Farm Exits	Number	20,818	20,773	16,790	12,547
	% Initial	(39)	(40)	(40)	(40)
Tobacco Exits	Number		11,512		13,242
	% Initial		(22)		(43)
Continuers	Number	32,831	19,024	25,516	5,293
	% Initial	(61)	(37)	(60)	(17)
	% Final	{80}	{65}	{84}	{65}
Tobacco Entrants	Number		2,179		530
	% Final		{7}		{7}
Farm Entrants	Number	8,229	8,034	4,770	2,290
	% Final	{20}	{27}	{16}	{28}
Final		41,060	29,237	30,286	8,113

Note: Operating farms consist of all KY farms that produced tobacco in any of the years 1997, 2002, or 2007. Data source: U.S. Census of Agriculture. Parenthesis () indicate proportion of initial farm numbers. Curly brackets {} indicate proportion of final farm numbers.

The relative characteristics of surviving tobacco growers, entrants, and exiters illustrate the ways in which the tobacco-sector dynamics changed following the buyout. Table 2 shows our estimates of the average tobacco acreages and farm sizes before and after the quota buyout. Average tobacco acres harvested on farms that produced tobacco in both 1997 and 2002 decreased 36 percent, even though the average size of these farms increased from 82 to 95 acres.[16] Interestingly, average tobacco yields on these continuing farms also decreased slightly. Farms that produced tobacco in both 2002 and 2007 tended to be larger, and their average tobacco acreage increased from 8.7 to 12.2. The average tobacco acreage share of these farms increased somewhat, and their average tobacco yield increased significantly from 2,079 to 2,247 pounds per acre. The third and seventh rows of table 2 show that farms that exited tobacco production between 1997 and 2002 or between 2002 and 2007 tended to be smaller than continuers in the same year, both in terms of farm size and tobacco acreage, and they tended to have lower tobacco yields.

The difference between pre- and post-buyout dynamics may, in part, be due to farmers who started growing tobacco simply to claim the grower's benefit in the buyout. Notably, entrants between 1997 and 2002 had lower yields in 2002 than exiters did in 1997. In contrast, the entrants between 2002 and 2007 were significantly larger, more productive, and harvested more than double the tobacco acreage. Finally, more than 87 percent of the 1997–2002 entrants exited tobacco production after the buyout.

Clearly a significant amount of acreage allocated to tobacco production in Kentucky was reallocated among farms in the years after the quota buyout. Under the tobacco program, growers could not easily shift tobacco production across counties in Kentucky. After the buyout, tobacco acreage shifted from eastern to central and western Kentucky, with every county in the Eastern district decreasing acreage, and some counties in the central and western districts increasing acreage. The Eastern district had the highest average production costs in 2002. However, the relationship between production costs and post-buyout tobacco acreage growth was not

were in both the 2002 and 2007 Censuses (with the same identifier in both years), and produced tobacco in 2007 but not in 2002. Some of these "entrants" in 2007 may have been existing tobacco farms that were unable to obtain quota in 2002 because quota owners were using their quota to take advantage of the grower benefit. We also found similar rates of entry and exit using other data sources. We provide a detailed description of our robustness checks in a supplementary appendix online.

[16] In comparison, total U.S. burley acreage fell 47 percent between 1997 and 2002.

Table 2. Tobacco Acreage and Farm Size of Continuers, Entrants, and Exits, Kentucky Tobacco Farms, 1997-2007

Panel Period	Group	Mean (s.d.) of Tobacco Acreage Harvested	Mean (s.d.) of Total Acreage Harvested	Mean (s.d.) of Acreage Share of Tobacco	Mean (s.d.) of Tobacco Yield (lbs./acre)
1997 to 2002	Continuers (1997)	7.2	82.0	0.40	1964.8
		(11.4)	(280.0)	(0.40)	(588.2)
	Continuers (2002)	4.6	94.8	0.31	1909.8
		(8.1)	(317.2)	(0.40)	(656.0)
	Exiters (1997)	4.8	52.7	0.48	1874.0
		(7.4)	(185.6)	(0.44)	(606.6)
	Entrants (2002)	4.1	84.3	0.38	1821.3
		(6.8)	(268.1)	(0.43)	(684.7)
2002 to 2007	Continuers (2002)	8.7	171.9	0.26	2079.1
		(12.9)	(507.6)	(0.36)	(625.4)
	Continuers (2007)	12.2	179.1	0.29	2247.1
		(21.2)	(522.5)	(0.36)	(661.7)
	Exiters (2002)	3.5	74.2	0.35	1837.9
		(5.6)	(232.6)	(0.42)	(668.0)
	Entrants (2007)	11.0	120.0	0.37	2154.4
		(18.3)	(292.6)	(0.40)	(697.2)

Sources: 1997, 2002, and 2007 Censuses of Agriculture (long and short forms). Standard deviations in parentheses.

monotonic.[17] Economic theory predicts that quota rental rates should be higher in counties with lower marginal costs of production (Rucker, Thurman, and Sumner 1995). The pairwise correlations between county-level quota rental rates in 1997, 2002, and 2004 and the 2002–2007 county-level growth of tobacco acreage are, respectively, 0.30, 0.19, and 0.40. Taken together, the evidence on geographic variation in tobacco acreage growth, quota rental prices, and production costs suggests that although costs of production were an important part of the story, they do not explain all of the reallocation of tobacco acreage. To fully understand how the reallocation affected aggregate productivity growth, we also need to take account of the reallocation of inputs other than land. We turn to this growth accounting next.

Estimation Results

Table 3 shows our estimates of the output elasticities for Kentucky tobacco farms. They are evaluated at the sample mean for each of the three aforementioned production function estimators. Robust standard errors are shown in parentheses. The parameter estimates are all statistically significant at standard significance levels, and the estimates are remarkably similar across all three estimators. Kentucky tobacco farms seem to exhibit increasing returns to scale in this period.[18]

Table 3. Mean Output Elasticities, Kentucky Tobacco Farms, 1997–2007

Input	(1) OLS	(2) OLS with County Fixed Effects	(3) Levinsohn & Petrin
Land	0.216	0.229	0.224
	(0.006)	(0.006)	(0.006)
Intermediates	0.531	0.519	0.482
	(0.005)	(0.006)	(0.007)
Capital	0.098	0.090	0.088
	(0.006)	(0.006)	(0.024)
Labor	0.324	0.288	0.306
	(0.012)	(0.012)	(0.011)
Livestock	0.064	0.062	0.063
	(0.001)	(0.001)	(0.002)

Sources: 1997, 2002, and 2007 Censuses of Agriculture
Note: All observations in 1997, 2002, and 2007 are pooled to estimate the production functions. Sample size is 33,827. The table shows output elasticities evaluated at the sample mean. Robust standard errors in parentheses.

[17] We provide more detailed analysis of tobacco acreage shifts and production costs by county and district in a supplemental online appendix.

[18] We also estimated a Cobb-Douglas specification of the production function, which constrains the coefficients on the squared

Table 4. Aggregate Productivity Growth Decompositions, Kentucky Tobacco Farms, 1997-2007

	1997–2002			2002–2007		
APG Component	OLS (1)	Fixed Effects (2)	L-P (3)	OLS (4)	Fixed Effects (5)	L-P (6)
Aggregate Productivity Growth	−7.1%	−7.1%	−7.1%	44.4%	44.4%	44.4%
Input Reallocation	3.3%	3.3%	3.5%	7.9%	7.6%	8.3%
Quota Reallocation	6.3%	6.3%	6.3%	na	na	na
Technical Efficiency Growth	−10.1%	−10.2%	−10.5%	−6.3%	−6.0%	−6.7%
Residual	12.7%	12.8%	12.9%	22.7%	22.7%	22.7%
Farm Entry & Exit	−23.2%	−23.2%	−23.2%	6.2%	6.2%	6.2%
Tobacco Entry & Exit	4.1%	4.1%	4.1%	13.9%	13.9%	13.9%

Sources: 1997, 2002, and 2007 Censuses of Agriculture.
Note: Residual for 2002–2007 includes elimination of quota rental costs.
na = not applicable.

Table 4 shows our estimates of aggregate productivity growth and its decomposition for Kentucky tobacco farms for 1997 to 2002 and 2002 to 2007 using equation (12). Columns (1)-(3) report the OLS, fixed effects, and Levinsohn-Petrin estimates, respectively, for 1997–2002 aggregate productivity growth. The D-F APG measure shows that the aggregate productivity of Kentucky tobacco farms decreased by 7.1% between 1997 and 2002.[19] The second row shows the total contribution of input reallocation among continuing tobacco farms. Using the L-P estimator (column 3), we find that this reallocation contributed 3.5 percentage points to aggregate productivity growth. The third row shows the *direct* contribution of the reallocation of quota among continuing farms, *holding quota rental prices constant*. Continuing tobacco farms reduced their tobacco production over this period (see table 2), so they also reduced their usage of quota, directly contributing 6.3 percentage to APG. Aggregate technical efficiency growth of continuing farms contributed −10.5 percentage points. The fifth row shows that the residual term specified in equation (13) accounted for 12.9 percentage points of APG. In the sixth and seventh rows, we disentangle the contributions of farm entrants/exits and tobacco entrants/exits, respectively, as defined in the previous section.[20] From 1997 to 2002 we find that net farm entry contributed −23.2 percentage points to aggregate productivity growth. On the other hand, net tobacco entry contributed 4.1 percentage points to APG. The estimates using OLS and county fixed effects (columns 1 and 2) are essentially the same, except that the L-P estimator attributes slightly more positive growth to input reallocation and slightly more negative growth to technical efficiency decline among continuing tobacco farms.

Negative aggregate productivity growth between 1997 and 2002–especially the large contributions of farm net entry and negative technical efficiency growth among continuers–warrants some explanation. The "grower benefit" in the quota buyout created incentives for farmers to become/remain tobacco growers. The results of these incentives can be seen in the anomalous characteristics of tobacco

and interaction terms in equation (14) to equal zero. The estimated output elasticities are similar. However, an F-test strongly rejects the hypothesis that the squared and interaction terms in (14) are jointly zero. We present the Cobb-Douglas estimates in the online supplemental appendix.

[19] According to the USDA Agricultural Productivity Accounts, total factor productivity for *all* Kentucky farms fell by 4.3% from 1997 to 2002.

[20] To the extent that our "farm entry" and "farm exit" measures are capturing changes in farm identifiers, those "entrants" and "exits" are all accounted for by the sixth row of the table.

entrants between 1997 and 2002, as noted in the previous section and in table 2. This may explain the large negative contribution of farm net entry, as quota owners entered tobacco production to take advantage of the grower benefit. The grower benefit also provided an incentive for tobacco growers to continue production when they otherwise might have exited. Since the grower benefit was the same (per pound of tobacco) for all growers, it was more likely to affect the exit decision of less profitable growers. Profitability and productivity tend to be positively correlated, so less productive growers may have continued producing in 2002–2004 so that they could receive the grower benefit. Growers who were planning to exit once the quota program ended also had little incentive to make productivity-enhancing investments in their tobacco enterprise in the years leading up to the buyout. Thus anticipation of the quota buyout may have lowered the aggregate productivity of tobacco growers between 1997 and 2002.

Columns (4)–(6) of table 4 show APG and its decomposition for 2002 to 2007 using equation (12). In stark contrast to the earlier period, we find that the aggregate productivity of Kentucky tobacco farms grew by 44% between 2002 and 2007. As expected, after the quota buyout, input reallocation among continuing tobacco farms contributed positively, adding 8.3 percentage points to aggregate productivity growth according to the L-P estimator. As noted above, we cannot separately measure the *direct* APG contribution of the elimination of quota, because all farms had zero quota after the buyout. Aggregate technical efficiency growth among continuing tobacco growers contributed −6.7 percentage points. The residual term for continuers, which includes the contribution of eliminating quota, was the most important factor, accounting for 22.7 percentage points of our APG measure. Farm net entry contributed 6.2 percentage points to aggregate productivity growth as smaller, less productive farms exited and larger, more productive farms entered. Finally, existing farms that entered or exited tobacco production contributed 13.9 percentage points to APG after the buyout. Once again, the results for the OLS and the county fixed effects estimators (columns 4 and 5) are similar.

Aggregate productivity growth of 44% between 2002 and 2007 implies an average annual productivity growth rate of about 7.6%. Although this is quite high, it is not implausible given the distortions tobacco growers faced before the buyout and the large, rapid consolidation of resources that occurred afterwards. Between 2002 and 2007, the total number of tobacco-producing farms in Kentucky declined by 74%, and the average tobacco acreage per tobacco-producing farm increased 168%–from 4.4 acres per farm in 2002 to 11.8 in 2007. To put this into perspective, the average acreage size of all U.S. farms increased by “only” 96% between 1982 and 2002 (Key and Roberts 2007). Over the same period, according to the USDA Agricultural Productivity Accounts, U.S. agricultural productivity increased by 38%.[21] The production function estimates in table 3 indicate that tobacco farms faced increasing returns to scale. Before the buyout, the restrictions on inter-county transfers of quota prevented some growers from taking advantage of these returns to scale. Furthermore, in the final years of the tobacco program quota rental prices in Kentucky averaged 30% of the price of burley leaf, and in some major tobacco-producing counties the price of quota rental was as much as 40% of the price of burley leaf. As table 4 shows, the residual term including the elimination of quota rental costs accounted for half of total APG between 2002 and 2007.

Negative technical efficiency growth among continuing farms between 2002 and 2007 also deserves an explanation. As noted above, our measure of farm-level technical efficiency growth is the residual from a regression of deflated revenue on similarly deflated inputs. This implies that our measure of farm-level technical efficiency growth includes measurement error due to the differences between the growth rates of the prices of tobacco and other outputs and the growth rate of the output price index. In particular, after the buyout the price of burley tobacco fell faster than the output price index, adding negative measurement error to our estimates of technical efficiency growth.[22]

[21] Of course, returns to scale do not explain all of the productivity growth of U.S. farms between 1982 and 2002, but the same is true of Kentucky tobacco farms–other factors also affected aggregate productivity growth. The point of this comparison is that the massive reallocation of resources in Kentucky tobacco production happened very quickly after the buyout. To see a similar reallocation of resources at the more aggregated level, one has to look at a longer time frame.

[22] This type of measurement error does not affect our estimate of overall APG–it only affects the decomposition of APG into technical efficiency growth versus reallocation.

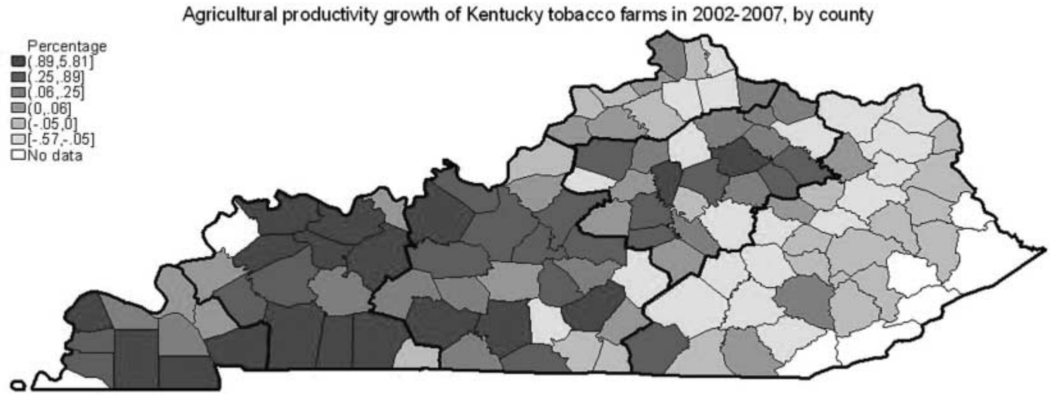

Figure 1. Productivity growth of Kentucky tobacco farms 2002–2007, by county

Sensitivity Analysis

The APG decomposition allows us to account for the contribution of each geographic region to aggregate productivity growth. Figure 1 shows the contribution of each county to the aggregate productivity growth of tobacco farms between 2002 and 2007 using equation (10). Most counties in eastern Kentucky contributed little to aggregate productivity growth, whereas many central and western counties contributed positively. This is consistent with economic intuition–we expect to see more aggregate productivity growth in counties to which resources are being reallocated.

Tobacco Specialization

We have selected farms that produced tobacco between 1997 and 2007. Most Kentucky tobacco farms also produce other products. Although the Agricultural Census data does not allow us to distinguish between inputs (other than land) used for tobacco versus other crops, it does allow us to distinguish between outputs. Farms that were less dependent on tobacco revenue might have responded differently to the quota buyout, or might have affected aggregate productivity growth in different ways. To test this hypothesis, we divided Kentucky tobacco farms into three groups based on the share of their sales coming from tobacco: less than 50%, 50 to 90%, and greater than 90%.[23] Row 1 of table 5 shows the percentages of our sample accounted for by each group in each period. As shown in table 2, after the buyout Kentucky tobacco farms diversified. The least tobacco-dependent group increased from 41 to 47% of the sample, and the most tobacco-specialized group decreased from 31 to 25% of the sample.

For each tobacco sales share group, we computed its contribution to the total APG of tobacco farms and to each component of the P-L decomposition.[24] Between 1997 and 2002, tobacco farms with less than 50% of their sales from tobacco contributed (positive) 6.2 percentage points to APG, counterbalancing the −6.1 percentage points contributed by farms with tobacco sales shares of 90% or more. The least tobacco-dependent farms may have been better able to reduce their tobacco acreage in the face of increasing quota rental costs leading up to the buyout. Our results are consistent with this hypothesis–quota reallocation among highly tobacco-specialized continuing farms contributed less than 1 percentage point to APG, compared to 2.6 and 2.8 percentage points for the less tobacco-dependent groups. After the buyout, tobacco farms with less than 50% of their sales from tobacco accounted for almost all of the APG of tobacco farms over that period. The least-specialized group contributed more to total APG after the buyout in part simply because they accounted for a larger share of both tobacco production and the total production of tobacco farms. For the least tobacco-specialized farms, the direct effect of the elimination of quota rental costs (plus the price change residual) was the most important factor in APG after the buyout, contributing 19.6 percentage points. The

[23] For continuing farms, the tobacco sales share is from the base year (e.g., 2002 for farms that continue from 2002 to 2007).

[24] Columns 1-3 of table 5 sum to column 3 of table 4. Columns 4-6 of table 5 sum to column 6 of table 4.

Table 5. Aggregate Productivity Growth Decomposition by Tobacco Sales Share, Kentucky Tobacco Farms, 1997–2007

	1997–2002			2002–2007		
	< 50% (1)	50–90% (2)	> 90% (3)	< 50% (4)	50–90% (5)	> 90% (6)
Proportion of Sample	41%	28%	31%	47%	27%	25%
APG Component						
Aggregate Productivity Growth	6.2%	−7.2%	−6.1%	43.1%	2.6%	−1.2%
Input Reallocation	1.9%	1.6%	0.0%	5.1%	2.2%	1.0%
Quota Reallocation	2.6%	2.8%	0.9%	na	na	na
Technical Efficiency Growth	−4.1%	−3.1%	−3.2%	−3.4%	−2.1%	−1.1%
Residual	7.1%	2.6%	3.1%	19.6%	2.8%	0.3%
Farm Entry & Exit	−5.3%	−10.9%	−7.1%	4.4%	2.6%	−0.8%
Tobacco Entry & Exit	4.1%	−0.3%	0.2%	17.4%	−0.9%	−0.6%

Sources: 1997, 2002, and 2007 Censuses of Agriculture.
na = not applicable.

second most important factor was the contribution of tobacco entry/exit, accounting for 17.4 percentage points.

As noted above, our estimates of farm-level technical efficiency growth include measurement error due to differences between the growth rates of the prices of tobacco and other outputs and the growth rate of the output price index. Since the price of tobacco dropped more than the output price index after the buyout, more specialized tobacco farms are more affected by this negative measurement error. Our results are consistent with this hypothesis. The unweighted average of technical efficiency growth of the most tobacco-specialized farms was more negative than the unweighted average of the least tobacco-dependent farms.[25]

Conclusions

We study the impact of the U.S. tobacco quota program and the 2004 quota buyout on the aggregate productivity growth of tobacco farms in Kentucky. We find that aggregate productivity decreased by 7.1% between 1997 and 2002, but grew by 44.4% between 2002 and 2007. Between 1997 and 2002, technical efficiency growth of continuing tobacco farms contributed about −10.5 percentage points to aggregate productivity growth, while reallocation of resources among continuing tobacco farms contributed 3.5 percentage points; net exit contributed −19.1 percentage points. Reduction and reallocation of the quota rental costs of continuing tobacco farms (holding prices constant) directly contributed 6.3 percentage points. A residual term which accounts for changes in relative prices contributed the remaining 12.9 percentage points. Between 2002 and 2007, technical efficiency growth of continuing tobacco farms contributed −6.7 percentage points. Reallocation among continuing tobacco farms contributed 8.3 percentage points, and net entry between 2002 and 2007 contributed 20.1 percentage points. A residual term, which in this case includes the elimination of quota rental costs, accounted for the remaining 22.7 percentage points. After the buyout, tobacco production shifted from eastern to western Kentucky. Although the number of tobacco farms decreased in every county, total tobacco acreage increased in some western counties.

[25] Although less tobacco-dependent farms contributed more to the decline in aggregate technical efficiency after the buyout, this was entirely because these farms accounted for a larger share of the total production of tobacco farms.

Although our empirical results are generally consistent with economic theory, we interpret our measurements of entry and exit with some caution. Although we have conducted several robustness checks using different datasets and alternative definitions of entry and exit, we still find a surprising number of "new farms" entering tobacco production during a period in which the demand for U.S. burley tobacco leaf was in decline. Further research and better data on the entry and exit of tobacco farms (and farm entry and exit more generally) may be needed.

Our finding that resource reallocation (including entry and exit) made a large contribution to aggregate productivity growth contrasts with previous research on aggregate productivity growth in U.S. agriculture. Using aggregate state-level data, Ball et al. (1999) find that resource reallocation across states had little effect on aggregate productivity growth in agriculture. To the extent that resource reallocation is occurring within states more than across states, our results highlight the importance of using highly disaggregated data to study the sources of aggregate productivity growth. Our results also show the importance of using an aggregate productivity decomposition that allows for gaps between marginal revenue products and marginal costs. In tobacco production, these gaps were probably the result of the quota program, which in most states (including Kentucky) did not allow quota to be reallocated across counties. In other industries, these gaps could exist because of markups, adjustment costs, subsidies, or other distortions. To the extent that agricultural production–in the U.S. or anywhere–can be characterized as a sector in which subsidies, quotas, or other distortions are important, reallocation of resources probably plays an important role in aggregate productivity growth in the entire sector.

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